SOIL WATER USE BY APPLE TREES

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Pudjo RAHARDJO

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A B S T R A C T

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The study investigated the soil water use of an unirrigated tree and an irrigated apple tree in Hawke's Bay, New Zealand in the middle of the summer of 1988/1989. A rainout shelter was used to eliminate any water inputs from both irrigation and rain to the unirrigated tree. The irrigated tree received water inputs from both irrigation and rain. The soil water content was measured by neutron probing and time domain reflectometry. The heat pulse technique was used to measure the sap-flow in the apple trunks. Both leaf water pressure potential and stomatal resistance were measured by the pressure chamber and porometer respectively. A measuring cylinder was used to monitor the apple growth during the study.

The results of the water use measurements were that

- the neutron probing and time domain reflectometry showed the soil water use was about 77 litres (4.3 mm) per day taken from 0 - 1900 mm depth around the irrigated tree. However soil water extraction around the unirrigated tree was only 19 litres (1 mm) per day at the beginning of the study, and no water extraction was measured from the top 1900 mm later in the study.
- the heat pulse technique showed that the unirrigated tree extracted slightly more soil water than the irrigated tree. The average sap-flow measured was 66 litres per day. Probably the unirrigated tree extracted much of its water from below 1900 mm depth, or from beyond the covered area.
- the amount of water use by the apple trees was similar to regional evaporation estimates obtained using the Priestley - Taylor formula, when 0.66 fractional canopy cover was assumed.

The water stress monitoring showed that
e pressure chamber technique was a more sensitive way to monitor ress than was porometry.
e leaf water pressure potential values showed a significant fference between the irrigated and the unirrigated apple tree ring the latter part of the study.

The readily available soil water storage capacity from 0 to 400 epth (the most active part of the root zone), from 0 - 1000 mm h, and from 0 to 1900 mm, was about 36 mm, 89 mm and 170 mm ectively. When there was a lack of available soil water on the oil, the root system was forced to extract soil water from deep in soil profile.

The comparison of apple fruit growth showed that during the last days of the study, the apples on the unirrigated tree grew more ly than those on the irrigated tree.

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CHAPTER I

THE WATER BALANCE OF APPLE TREES

1.1. INTRODUCTION

Fruit and vegetables are in the top six New Zealand exports, after meat, wool, butter, forest products, and aluminium and alloys. The value of fruit and vegetables is about 7 percent of the national export receipts. Apples are the second most important commodity in the fruit export sector after kiwifruit (HEDC, 1982). The national apple production is about 155 million tonnes/annum (Wong, 1987). Thus apples are an important New Zealand export commodity.

Apple orchards usually use irrigation systems to overcome soil water deficits during dry periods when evaporation is greater than rainfall, and so to obtain the maximum yield and fruit quality. Using an irrigation system involves defining when and how the optimal amount of water should be applied in an orchard. Otherwise the orchard will received either over-irrigation or under-irrigation. Over-irrigation has several disadvantages, namely :

- higher irrigation expenses,
- nutrient leaching which can affect ground water quality and increase fertiliser cost,
- plant health problems due to water logging,
- decreased yield and fruit quality

On the other hand, under-irrigation causes plants to become unhealthy due to water stress and low soil nutrient availability. Thus it is important to investigate the amount of irrigation needed.

Irrigation is a water input, which is a component of the water balance. The understanding of the balance of the water inputs and outputs in an apple orchard is very important, because an unfavorable water balance can affect the apple tree development which can affect the export quantity and quality.

1.2. THE WATER BALANCE

Mass conservation can be used to explain the soil water balance (Hillel, 1982). In the root zone of an orchard over any time interval Δt, the change in storage equals the water inputs minus the outputs.

The inputs are rainfall (R) and irrigation (I), and the outputs are evaporation (E), drainage below the root zone (D) and surface runoff (S). In this thesis evaporation refers to all water vapour loss to the atmosphere, and so includes transpiration, evaporation from the soil and evaporation of intercepted water. So

$$\Delta W = R + I - E - D - S \qquad (1.1)$$

where ΔW is the change in the water storage in the root zone, and all terms have dimensions of length, being equivalent depths of water.

1.2.1. WATER INPUTS

Water inputs in the orchard are rainfall and irrigation water. Rainfall and irrigation are treated as independent variables and must be measured (Scotter et al., 1979). When water inputs bring the soil to "field capacity", then the soil water deficit is assumed to be zero (Taylor and Ashcroft, 1972). Excess water input leads to water redistribution and drainage beyond the root zone. But drainage losses during summer will be small if the irrigation system is well managed.

In orchards infiltration with water ponded on the surface is rare. It usually only occurs during heavy rain and on less permeable soils. Most of the water falling on the land, as either rain or sprinkler irrigation, infiltrates as unsaturated flow (Philip, 1969).

1.2.2. WATER OUTPUTS

Given no surface runoff, the water outputs in the orchard are evaporation, and drainage water, which only occurs when there is excess water input. The understanding of evaporation is very important in agriculture and horticulture because evaporation is a major term in the soil water balance.

When the humidity in the atmosphere outside the leaf cuticle is lower than in the intercellular spaces within a leaf, there is molecular diffusion of vapour outwards through the stomata. The number and degree of opening of the stomata, and the humidity gradient control the rate of diffusion. The continual transpiration from leaves needs three physical conditions. Firstly, a supply of energy must be available to provide the quite large latent heat of vaporation. Secondly, there must be a lower vapour pressure in the surrounding air than at the evaporating surface. Thirdly, there must be a continuous supply of water. This is the rate limiting factor for transpiration in dry condition (Rose, 1966; Meidner and Sherif, 1976; Milburn, 1979).

Transpiration from plant leaves causes a water potential gradient between leaves and roots. The root water absorption and sap flow depend not only on the leaf water potential, but also on the soil water potential and hydraulic conductivity. On the other hand, the atmospheric environment largely determines the rate of evaporation from the leaves, because the opening of stomata depends on environmental variables such as the solar radiation received, and the humidity gradient between inside and outside the stomata. Thus, the whole soil-plant-atmosphere continuum affects the amount of water lost by evaporation (Philip, 1966). Often however the atmosphere has the dominant effect on the rate of evaporation as the process is usually energy limited.

When evaporation from bare soil can be ignored, such as in a region which is completely covered by vegetation, and soil water is always available, the root water extraction rate can be assumed to be equal to the evaporation rate. Then, provided adequate soil water is available, estimates of regional evaporation using climate data can be used to estimate root water extraction (Thornthwaite, 1948; Blaney and Criddle, 1950, Penman, 1948, Priestley and Taylor, 1972). The actual evaporation is usually measured only for research purposes.

1.3. THE STUDY

The aim of the study was to investigate the soil water use by two apple trees in Hawke's Bay.

One apple tree was covered by a rainout shelter over the soil surface to eliminate any water input from irrigation and rainfall, and to prevent any water output from soil and grass evaporation. Thus transpiration is the only water use around this unirrigated tree.

The other apple tree had no any cover. This tree received water inputs from both irrigation and rainfall. The water use consisted of transpiration and both soil and grass evaporations around the tree.

The water use of both trees was investigated by using

- neutron probing and time domain reflectometry to monitor spatial and temporal soil water content changes, reflecting the root water extraction,
- the heat pulse technique to measure the sap flow in the tree,
- meteorological data to estimate regional evaporation around the orchard.

The unirrigated tree was expected to come under water stress, while the irrigated tree was expected to remain unstressed. To detect the level of plant water stress, a porometer was used to measure the stomatal resistance and a pressure chamber was used to measure the leaf water pressure potential. Soil matric potential was measured with tensiometers. Finally, a measuring cylinder was used to monitor the apple fruit growth on the two apple trees.